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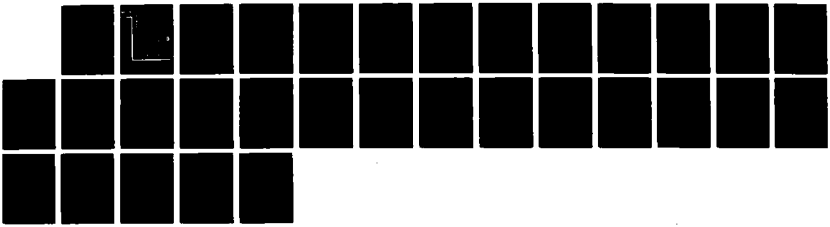

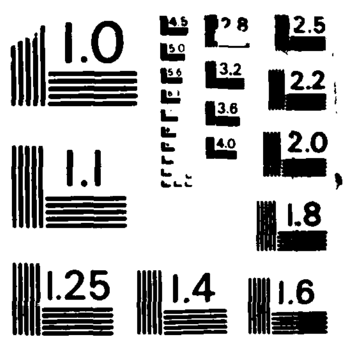

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AIR FORCE

HUMAN RESOURCES LABORATORY

AD-A179 251

FISCAL YEAR 1988 - AIR FORCE
TECHNICAL OBJECTIVE DOCUMENT

PLANS AND OPERATIONS OFFICE
Air Force Human Resources Laboratory
Brooks Air Force Base, Texas 78235-5601

April 1987

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AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5601

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This document provides the academic and industrial research and development communities with a summary of the technical objectives of Air Force efforts in the fields of training and personnel systems technology. The areas covered are (a) manpower and force management, (b) logistics technology, and (c) training technology.

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~~flying~~ training

human resources data in system design and operation

image generation

instructional systems

PREFACE

The Research and Technology (R&T) Plan is prepared each year by the Plans and Operations Office of the Air Force Human Resources Laboratory. The current version of the plan describes in general terms the work that is planned for FY88 to FY92 in the areas of manpower and force management, logistics systems technology, and training technology. The Technical Objective Document is extracted from the R&T Plan. For further information on these programs, inquiries should be addressed to the Plans and Operations Office (AFHRL/XO), Brooks Air Force Base, Texas 78235-5601.

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FISCAL YEAR 1988 - AIR FORCE TECHNICAL OBJECTIVE DOCUMENT

I. INTRODUCTION

The Air Force Technical Objective Document (TOD) program is an integral part of the process by which the Air Force plans and formulates a detailed technology program to support the development and acquisition of Air Force weapon systems. Each Air Force laboratory annually prepares a Research and Technology (R&T) Plan based on Air Force requirements, scientific and technological opportunities, and needs of present and projected systems. These plans include proposed efforts to achieve desired capabilities, to resolve known technical problems, and to capitalize on new technical opportunities. The proposed efforts undergo a lengthy program formulation and review process. Generally, the criteria applied during the formulation and review are responsiveness to stated objectives and known requirements, scientific content and merit, program balance, developmental and life cycle costs, and consideration of payoff versus risk.

It is fully recognized that the development and accomplishment of the Air Force technical program is a product of teamwork on the part of Air Force laboratories and the industrial and academic research and development (R&D) communities. The TOD program is designed to provide to industry and the academic community necessary information on the Air Force laboratories' planned technology programs. Each laboratory's TOD is extracted from its R&T Plan.

Specific objectives are (a) to provide planning information for Independent Research and Development (IR&D) programs, (b) to improve the quality of the unsolicited proposals and R&D procurements, and (c) to encourage face-to-face discussions between non-Government scientists and engineers and their Air Force counterparts.

One or more TODs has been prepared by each Air Force laboratory that has responsibility for a portion of the Air Force technical programs. All TODs are available from the National Technical Information Service and the Defense Technical Information Center.

As you read through the pages that follow, you may see a field of endeavor where your organization can contribute to the achievement of a specific technical goal. If such is the case, you are invited to discuss the objective further with the scientist or engineer identified with the objective. Further, you may have completely new ideas not considered in this document which, if brought to the attention of the proper organization, can make a significant contribution to our military technology. We will always maintain an open mind in evaluating any new concepts which, when successfully pursued, would improve our future operational capability.

On behalf of the Air Force, you are invited to study the objectives listed in this document and to discuss them with the responsible laboratory personnel. Your ideas and proposals, whether in response to the TODs or not, are most welcome.

II. HOW TO USE THIS DOCUMENT

Unsolicited proposals to conduct research leading to the attainment of any of the objectives presented in this document may be submitted directly to an Air Force laboratory. However, before submitting a formal proposal, we encourage you to discuss your approach with the laboratory point of contact. After such discussion or correspondence, you will be better prepared to write your proposal.

As stated in the "AFSC Guide for Unsolicited Proposals" (copies of this guide on unsolicited proposals are available by writing to Air Force Systems Command/PMPR, Andrews Air Force Base (AFB), Washington, DC 20334), elaborate brochures or presentations are definitely not desired. The "ABCs" of successful proposals are accuracy, brevity, and clarity. It is extremely important that your letter be prepared to encourage its reading, to facilitate its understanding, and to impart an appreciation of the ideas you desire to convey. Specifically, your letter should include the following:

1. Name and address of your organization.

2. Type of organization (profit, nonprofit).

3. Concise title and an abstract of the proposed research, and a statement indicating that the submission is an unsolicited proposal.

4. Outline and discussion of the purpose of the research, the method of attack on the problem, and the nature of the expected results.

5. Name and research experience of the principal investigator.

6. Suggestion as to the proposed starting and completion dates.

7. Outline of the proposed budget, including information on equipment, facility, and personnel requirements.

8. Names of any other Federal agencies receiving the proposal. (This is extremely important.)

9. Brief description of your facilities, particularly those that would be used in your proposed research effort.

10. Brief outline of your previous work and experience in the field.

11. Descriptive brochure and financial statement, if these are available.

III. LABORATORY MISSION

The Air Force Human Resources Laboratory (AFHRL) is the principal Air Force Systems Command (AFSC) organization charged with planning and executing the Air Force exploratory and advanced development programs for research related to manpower and force management, logistics systems technology, and training technology. Manpower and force management R&D addresses selection, classification, assignment, evaluation, and retention of Air Force members, and overall force structure and utilization. Logistics systems R&D is concerned with logistics factors at each step in the development and acquisition of weapon systems and the productivity of maintenance teams. Training technology R&D addresses the development of improved methods for aircrew training, command and control training, and technical training. Aircrew training R&D includes manned aircraft simulation, performance measurement, training technology for air combat tactics, and advanced systems to improve the quality and combat effectiveness of aircrews. Command and control R&D includes training to improve team performance, C^2 team performance assessment, and information systems to facilitate team performance. Technical training R&D includes the use of computer-assisted systems to improve training methods, instructional and learning strategies, techniques for managing training, and techniques for evaluating job performance.

IV. BASIC RESEARCH PROGRAMS (6.1)

AFHRL conducts basic research in the areas of learning abilities and perceptual dimensions of flight training. This research is accomplished in-house as well as by various contractors.

Learning Abilities Measurement Program (LAMP)

LAMP investigates the nature and organization of human learning abilities, with the ultimate goal of contributing to a new model-based selection and classification system for the Air Force. The program attempts to define systems for measuring fundamental human characteristics such as information processing speed, working memory capacity, and parameters associated with the factual and procedural knowledge bases. LAMP research conducted thus far has resulted in a tentative model of the mental skills responsible for the ability to learn. The model states that an individual's skill and knowledge levels vary along four major dimensions: working memory capacity, information processing speed, factual knowledge, and procedural or strategic knowledge. The model also assumes that these four source skills interact. The importance of having a model of learning ability is that the model can suggest means for constructing new kinds of ability tests, and can also serve as the basis for new task analysis systems. The model will eventually help specify what kinds of cognitive skills ought to be measured in order to develop equations for predicting the likelihood that a person will succeed in training and on the job.

Perceptual Dimensions of Pilot Behavior

This research explores the limits and capabilities of human perceptual processes pertinent to pilot training and simulator development. Cognitive as well as sensory dimensions of perception are addressed, since these factors rarely operate in isolation. Previous efforts in this area addressed problems in color vision, visual attention, and the perception of motion from visual cues alone. Color vision research centers on the interaction between color and apparent brightness, and the effects of adjacent colors on perceived contrast. Results to date indicate (a) pupil size affects apparent color, and (b) organizational differences exist in both normal and color-defective vision. Future research will explore the directional sensitivity of the eye across the color spectrum. The visual attention research is directed toward examining the differences between voluntary versus involuntary shifts in visual attention and the predictability of eye movement sequences. Thus far, research indicates the speed of voluntary shifts in attention can be dramatically improved with training (from 300 ms to 30 ms). The direction of this effort will be twofold. First, the generality of voluntary attention speed gains will be determined. Ultimately, the goal is to develop an artificial intelligence-based model of visual attention. Visual motion research deals with determining the key visual dimensions for motion cueing. This research has shown that the effects of optical flow rate and edge rate are independent and additive. Plans for this effort are to transition from data collected on passive observers to data for subjects involved in active flight control. Expected products of existing and planned research include: guidelines for the enhancement of simulator scene resolution by systematic application of simultaneous color contrast effects, and an artificial intelligence-based model of visual attention for pilot tasks.

V. TECHNOLOGY PROGRAMS (6.2 AND 6.3)

Manpower and Force Management

General Objective

The objectives of this R&D are to develop better ways of selecting people and assigning them to Air Force specialties; to determine job and training requirements for specialties; and to estimate the impacts of policy changes on the manpower and personnel process. The results will provide the basis for a variety of manpower and personnel policy decisions. Better methods are being developed for the procurement and selection of quality personnel; for the assignment of people to jobs compatible with their aptitudes, interests, and experience; for the establishment of effective reenlistment and career development programs; and for the design of improved decision aids for Manpower, Personnel, and Training (MPT) management.

Specific Goals and Technical Approaches

1. Force Acquisition and Distribution System. Technologies developed in this program will provide the Air Force with better ways of: analyzing jobs and determining job requirements; assessing the qualifications of personnel for a variety of different job assignments; and assigning personnel to manpower slots in ways that will maximize the cost effectiveness of Air Force systems.

a. Job Analysis and Job Requirements. Projects during FY88 to FY92 will continue to develop new and improved job analysis and job requirements data bases for Air Force use. These include: learning difficulty indices, which are used to decide what the aptitude requirements for jobs should be (FY88); a technology for measuring transferability of skills (FY89); transferability of skills matrices (FY91); procedures for a "cross-walk" between data bases in which inputs from the Logistics Composite Model (LCOM), Logistics Support Analysis (LSA), Maintenance Data Collection System (MDCS), and Occupational Measurement Center (USAFOMC) data bases will be consolidated (FY90); task analysis techniques for pilot task demand analysis (FY90); skill, knowledge, and ability inventories for assessing the commonality of job requirements (FY90); and techniques for identifying peacetime and wartime requirements for tasks (FY92). Advanced development work will be conducted for the Comprehensive Occupational Data Analysis Programs (CODAP) Analytic System, which is used for occupational analysis by the Air Force. Efforts include: nonhierarchical task clustering methods (FY88) and expanded analytical capabilities for the present CODAP system (FY90). These capabilities will pave the way for an advanced version of CODAP, which is scheduled for test and evaluation in FY92. Many of the CODAP data bases are input to the Occupational Research Data Bank (ORDB), an AFHRL-developed information system that is used extensively by many organizations including the Air Staff, the Military Personnel Center, and the USAFOMC at Randolph AFB. The ORDB will be enhanced in FY89 to allow for limited modeling and investigation of occupational structures.

b. Personnel Assessment Systems. Although personnel selection tests are well established in the Air Force, considerable R&D is required to maintain the existing measurement systems and develop new ones that can capitalize on recent developments in computer technology. The work on the Armed Services Vocational Aptitude Battery (ASVAB) uses exploratory development (6.2) as well as advanced development (6.3) funds. New and improved versions of the ASVAB will be developed in FY88 (ASVAB Forms 15, 16, and 17), FY90, and FY92. A prototype computer-assisted testing version of the ASVAB will be tried out and evaluated in a demonstration model (FY88). A special version of the ASVAB intended for use in the Department of Defense (DOD) student testing

program will be developed in FY90. In FY92, using performance tests developed as a result of other AFHRL efforts, the ASVAB will be subjected to performance validation investigations in addition to the training success validation investigations that are routinely conducted. Another test for which AFHRL is responsible is the Air Force Officer Qualifying Test (AFOQT). An improved version of the AFOQT (AFOQT-Q) will be developed in FY90. R&D on personnel assessment systems for aircrew personnel will also be conducted. In 1986, a first-generation Pilot Candidate Selection Method (PCSM) was developed and transitioned to Operational Test and Evaluation (OT&E) within the Air Training Command (ATC) and operational use within the Air National Guard (ANG). The PCSM uses a transportable and highly flexible computer-based testing system--the PORTA-BAT--to provide test scores which are then integrated with normally available aircrew selection information. The first-generation PCSM combined scores from two PORTA-BAT psychomotor tests with grades from the Flight Screening Program, scores from the AFOQT, and the candidates' ages. In 1988, a second-generation PCSM will be developed, also including information processing and decision-making tests. In 1990, a third-generation PCSM will be developed and expanded to include tests of attention sharing and personality factors. Using a similar approach, in 1989, an experimental track selection system for Specialized Undergraduate Pilot Training (SUPT) will be developed to classify students for advanced training in either Fighter-Attack-Reconnaissance (FAR) or Tanker-Transport-Bomber (TTB) aircraft.

In 1991, an operational version of the SUPT selection system will be developed. A new approach to personnel assessment and training will be investigated in FY88. Based on cognitive task analysis of Air Force Specialty Codes (AFSCs), improved diagnostic tests to identify basic skill deficiencies will be developed. This work will be followed up by a 6.3 basic skills project which will be training- as well as testing-oriented. A prototype basic skills training program will then be developed and validated against measures of job effectiveness. Diagnostic tests and training programs will be developed for additional AFSCs during FY88 to FY92. A complete basic skills testing and training program will be transitioned to the Air Force for operational use in FY92.

c. Personnel Classification and Assignment Systems. The complexity of the Air Force manpower and personnel system becomes obvious when it is time to assign thousands of people to jobs in hundreds of different occupational specialties at Air Force bases worldwide. These decisions must be made in ways that will maximize the payoff for the Air Force while simultaneously considering the needs and interests of the individuals to be assigned. Fortunately, computer technology has made it possible to address these problems in ways that would not have been possible in previous years. Both exploratory development (6.2) and advanced development (6.3) funds are involved. Systems to be developed include: a preliminary version of a system for Procurement and Classification of Enlistees (PACE) (FY88); improved classification algorithms for the PACE model (FY91); a person-job-match (PJM) model for retraining assignments (FY92); and a base assignment model that would maximize the payoff for the Air Force when personnel are assigned to specific jobs at specific base locations (FY92).

2. Force Management System. The decreasing applicant pool of Service-eligible personnel makes the effective use and increased retention of quality personnel critical goals for the Air Force. Decision aids and force management models are essential for those who make policy decisions. Moreover, these decision aids and policies need to be integrated and evaluated in terms of their total systems impact. There is, as a result, much emphasis in recent years on MPT integration systems. Productivity measurement systems are also needed for force management in order to determine if MPT policies and procedures are having the kinds of impacts that they are supposed to have.

a. Decision Aids and Force Management Models. New cost analysis and value assessment techniques will be developed in FY89: a cost of human capital methodology and a model for the value of Air Force experience. New manpower and personnel forecasting models will also be developed, including an equilibrium model for the enlistment and reenlistment markets (FY90).

b. Integrated MPT Planning Systems. Integration of MPT planning systems is needed at both the specific weapon system and aggregate levels in order to avoid disconnects and unexpected consequences for functional area managers. Planned MPT integration products include: aptitude requirements forecasting techniques (FY89); civilian/military availability model (FY90); an AFS structure simulation model (FY90); and an aggregate force impact model (FY93).

c. Productivity Measurement Systems. Productivity measurement systems are needed to determine if MPT policy decisions are having the kinds of impacts that they are supposed to have. Work has been conducted in this area as part of AFHRL's methodology for generating efficiency and effectiveness measures (MGEEM). Validation investigations of the MGEEM approach will continue, using various methods for assessing the improvements resulting from organizational interventions.

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Logistics Technology

General Objectives

This R&D will develop methods and strategies (a) to design new weapon systems that are more reliable and easily maintained; (b) to provide user-friendly computer-based automated aids to accomplish maintenance quickly and accurately in all environments; (c) to develop data bases and methods to accurately determine and provide for combat maintenance needs; and (d) to provide R&D support for the automation and integration of technical data. The products of work on these objectives influence Major Command (MAJCOM), USAF, and DOD policies for planning and managing logistics support for combat operations.

Information systems must be designed so people can quickly get the information they need for their immediate decision or task. Better information systems require better methods of interfacing computers and exchanging information among data bases; methods of data structuring; configuration management and control; methods of decision aiding; modeling and analysis; basic understanding of human/computer information processing capability to get the best of both; and methods for displaying information so that it is rapidly, easily, and correctly understood. R&D underway covers a broad spectrum, ranging from human information processing to the use of artificial intelligence (AI) to organize data bases. Planned technology developments will not only influence the design and acquisition of new weapon systems but also provide the technician with computer-based aids to maintain the weapon systems under austere deployed conditions.

Specific Goals and Technical Approach

1. Acquisition Logistics. Two high-level initiatives are spurring work in Acquisition Logistics. The Computer-Aided Logistics Support (CALS) program is a multi-Service program directed by the Office of the Secretary of Defense. The Unified Life-Cycle Engineering (ULCE) project technology is an important component of Forecast II--the Air Force Systems Command's effort to advance key military technologies and systems. The CALS program and the ULCE project technologies have complementary goals. CALS seeks to achieve improved supportability and sustainability through integration and automation of a large portion of the acquisition support process via networked information systems supporting the Computer-Aided Design (CAD) and

Computer-Aided Manufacturing (CAM) processes. The overall objective of ULCE is to develop, demonstrate, and transfer to application, by 1995, the technologies needed to provide integration of "design for producibility" and "design for supportability" with "design for performance, cost, and schedule." AFHRL work in acquisition logistics supports both CALS and ULCE.

a. Unified Data Base (UDB) for Acquisition Logistics. UDB is a Logistics Support Analysis Record data base system designed to improve the documentation and accessibility of acquisition logistics support data. UDB conforms to MIL-STD-1388-2A and automates all the data elements of this standard through the addition of data elements supplemental to the military standard. The system may also be used to automate common acquisition data items. The technology will provide consistent, traceable and easily used weapon system logistics data through the acquisition cycle and the transition of the systems to the Air Force Logistics Command (AFLC). The UDB technology will be linked with other CAD systems to allow the formulation of weapon system-specific data bases which will support design trade-off studies, reliability and supportability analysis, and other timely management studies. The UDB technology is being demonstrated on the F-15E aircraft. The technology will be transitioned to the Air Force Acquisition Logistics Center in FY88.

b. Reliability and Maintainability in Computer-Aided Design (RAMCAD). This effort will develop analytical models, computer software, data bases, and work procedures for including maintenance and logistics factors in the CAD of systems and equipment. Computer-aided engineering techniques have helped reduce the design burden, making it possible to now incorporate logistics and R&M considerations during the initial design phases. A wide spectrum of CAD technologies for industrial design are being developed in the commercial marketplace. These CAD technologies substantially enhance drafting capabilities and the hardware design process. Since maintenance and logistics considerations are not formally a part of the drafting process, there is little industrial motivation to develop and incorporate these aspects into CAD. RAMCAD provides the only Air Force funding for such efforts. RAMCAD will develop and demonstrate interactive computer techniques to design and evaluate the maintenance and logistics characteristics of weapon systems within a CAD environment. This includes development of techniques through a university-industry consortium and demonstration of ongoing weapon system development programs. To ensure continuity of effort, close coordination is being maintained with the National Security Industrial Association working group on RAMCAD and the Joint Logistics Commanders' working group for RAMCAD. The final demonstration and test of RAMCAD is scheduled in FY90.

c. Integrated Design Support (IDS) System. IDS will demonstrate advanced software and communication architectures for the coordination, preservation, and retrieval of weapon system engineering design technical data for DOD use (logistics, maintenance, remanufacturing, technical orders, etc.). DOD does not currently obtain or retain adequate technical information for the complete logistics support (remanufacturing, third-party parts suppliers, replacements for obsolete parts, etc.) of most weapon systems, making DOD dependent on primary contractor support for the life of the weapon system. The IDS program will develop a digital software architecture that will advance existing capabilities for the acquisition, storage, retrieval, coordination, and communication of weapon system technical design data, design specifications, manufacturing methods, and parts fabrication information. This effort is essential for future computer-based technical information systems and automated engineering data. New software and communication architectures are required to provide for engineering design, technical data communication, and data coordination for other DOD uses. Most of these technical data are available but there is presently no way to cost-effectively obtain and retain such data. IDS will be critical in providing an Air Force capability in this regard. A prototype IDS system demonstration in a production environment will be completed in FY91.

d. Design Analysis Models (CREW CHIEF). This R&D will develop a computer graphics model and supporting data bases of Air Force technicians (male and female) for use in

computer-aided methods of evaluating designs of weapon systems and equipment. The model will be used to perform mockup-type evaluations of new weapon system and equipment designs. Human-like characteristics such as standing, sitting, squatting, crawling, lifting, pulling, and tool usage will be featured in the model. This effort will encompass both male and female technicians and maintenance work in both standard work clothing and protective equipment. The model will be capable of evaluating a proposed design in maintainability terms such as accessibility of equipment, tool usage within access areas, maintenance operations and task requirements, and lifting load requirements. It can be used by designers to do on-line analysis during early stages of the design cycle. It holds the promise of reducing development costs, acquisition time, and life-cycle costs.

2. Logistics Resource Planning. This R&D provides the capability to analyze the Air Force-wide logistics concepts and resource requirements to enhance the logistics supportability of weapon systems. The work impacts the ability of Air Force personnel to conduct combat operations and augments the decision-making process within the logistics support structure.

a. Integrated Logistics and Operations Model. A basic problem exists in most models currently employed for capability assessment. Operations assessment models tend to aggregate and, in some cases, ignore logistics and maintenance aspects and impacts. On the other hand, logistics support assessment models tend to minimize operational input. Results of these deficiencies make the data output of both the logistics and operations models suspect. R&D to integrate various combat operations models with logistics assessment models has been initiated to formulate a "super" theater assessment model. The concept for a "super" model will include the formulation of a comprehensive, system-level, two-sided conflict where each force includes their respective concepts of operations. The R&D phase of the effort will be completed in FY89. Field testing, validation, and technology transition will be completed in FY91.

b. Wartime Logistics Demand Rate Forecasting. Although wartime logistics demand rate forecasting for specific aircraft subsystems (electronic countermeasures [ECMs], engines, and avionics) is being accomplished, there is a need to provide a means for predicting, measuring, and testing wartime demands for entire weapon systems. This effort will build upon the methodologies and models developed for the aforementioned specific aircraft subsystems to provide the tools for logisticians to accurately determine the spare parts required to maintain weapon systems in a combat environment.

c. Resource Quantification Methodology (RQM). This R&D is to develop an RQM using historical data and existing simulation and modeling techniques to quantify overall resource requirements for aircraft battle damage repair (ABDR) under combat conditions. The ABDR RQM is a joint effort by the AFHRL and the Air Force Wright Aeronautical Laboratories (AFWAL). As no model directly addresses the effects of ABDR on overall resource requirements, the completed R&D will integrate several existing computer models to determine resources (i.e., spares, manpower) required during a wartime environment to improve the aircraft sortie rate. This technology will be transitioned in FY88.

3. Combat Maintenance. R&D is being conducted to improve the readiness and capability of maintenance and logistics units to sustain the required aircraft sortie rate under wartime conditions. There are two major concentrations: improving the technical capability to do maintenance through advanced job aids and diagnostics; and techniques to improve combat maintenance assessment, readiness, and sustainability.

a. Integrated Maintenance Information System (IMIS). The Air Force now has or is developing several computer systems for use at base level to support maintenance and supply functions. Unless integration occurs, the Air Force of the future will have several incompatible computer systems on the flight line, with continuing update requirements for each. Confusion

will occur with possibly incompatible hardware, data requirements, and required training. The IMIS development will integrate these existing and developing systems with a computer-based technical information system, adding diagnostic job aids to increase the ability of technicians to troubleshoot and perform a wide range of maintenance actions. A demonstration on a fielded weapon system (F-16 aircraft) will be completed in FY88. The IMIS will provide an integrated approach to total weapon system maintenance. Technical data, training, diagnostics, management, scheduling, and historical data bases will be linked together, and a portable graphic display job aid will be developed to present the required information at the job site. Interfaces will be developed for aircraft computers and for existing and emerging data bases. This program will be closely coordinated with AFWAL and other concerned laboratories. Specifications and authoring systems for technical orders in electronic form will be targeted for implementation as Phase IV of the Air Force Automated Technical Order System (ATOS). A major application of this technology will be to the Advanced Tactical Fighter (ATF). IMIS will have several benefits. It will improve the use of the available manpower, enhance technical performance, improve training, and reduce the support equipment and technical documentation needed for deployment. IMIS may also eliminate the need for the Air Force to field several different computer systems, greatly reducing the need for unique hardware and software. Significant cost savings could be realized from the reduced training and system acquisition requirements. In addition, the diagnostics capabilities of IMIS will improve the efficiency of technicians to troubleshoot faults, resulting in savings in time to restore malfunctioning equipment to operational status, reduced consumption of spare parts, and improved operational readiness rates.

b. Combat Maintenance Readiness, Capability, and Sustainability. Methodologies are being developed to determine what tasks are essential to combat, and how organizations and procedures differ when they transition from peacetime to combat. One task will be to use the methodologies and data collected to develop and demonstrate combat-oriented operating practices and training programs. This work will build up on four ongoing efforts.

(1) AFSC Restructuring. Efforts in the FY86 to FY88 timeframe will develop methodology for assigning critical tasks to a limited number of personnel in an isolated, dispersed location. This will identify the minimum skills required to generate sorties in a dispersed location and help identify the AFSCs that could be broadened to reduce manpower requirements without a loss in combat sortie capabilities. Actual wartime data obtained from various sources will provide the basis for improved wartime logistics indicators, realistic estimates of resource requirements, and accurate projections of aircraft availability under combat conditions.

(2) Chemical Biological Warfare (CBW) Environment. Work will continue into FY92 on developing, analyzing, and testing methodologies for performing maintenance and related logistics functions in a CBW environment. Critical combat maintenance repair tasks will be identified; then, testing will be conducted to determine whether those tasks can be accomplished by personnel who are wearing CBW protective clothing.

(3) Stress Impact on Maintenance Performance. The stresses inherent in a combat environment have been overlooked because maintenance personnel have normally worked in a protected environment where air superiority was assured. Small initial efforts have validated the need for the work and identified potential academic sources of knowledge. Further R&D will identify sources of stress, controls for stress, and operational implications of stress, and attempt to quantify the impact of combat stress on the performance of technical tasks.

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Training Technology

General Objective

The general objective of training R&D is to identify and demonstrate cost-effective strategies and new training systems to develop and maintain combat effectiveness. These strategies and systems will result in higher personnel quality and increased combat readiness at optimum cost. The improvements in personnel quality are designed to reduce early loss rates in combat and increase the amount of equipment and personnel available for subsequent combat efforts. The reduced costs will make it possible to train more personnel for the same investment and permit more effective use of the limited training resources that are available for the acquisition and retention of complex combat skills.

Specific Goals and Technical Approaches

1. Aircrew Training Technology. The drive toward lower-cost simulators will be advanced through improved concepts for identifying training requirements and designing simulators. The application of new simulator technologies and aircrew training systems will permit savings by providing high-quality training at substantially reduced cost.

a. Requirements for Aircrew Training Devices. The most important goals for aircrew training are to identify the amount of simulator fidelity that is required and to determine the extent to which specialized training systems characteristics should be used to enhance training. This information is needed to help the designers of Air Force training systems decide "How much is enough for a given task?" With this objective in mind, priority has been given to five training requirement issues as part of a Training Effectiveness Plan (TEP) agreed upon by AFHRL and the organizations that make use of AFHRL products. The five component parts of this TEP are:

(1) Training System Design. A design specification was developed for a total training system that will effectively use a spectrum of training media, and integrate all phases of training from "cradle to grave." Military Airlift Command (MAC) and AFHRL have incorporated these concepts into the C-130 model aircrew training system (MATS). The program includes an aggressive evaluation of MATS and its major elements, as well as an R&D component to address performance measurement, instructional strategies, and cost/benefit issues in the context of the C-130 MATS. Contract award is anticipated to occur in the spring of 1987. Similar programs are anticipated for the B-52/KC-135 formal school and A-7/F-16 training with the Arizona ANG. Collectively, these programs will provide guidelines for designing courseware that fully uses the capabilities of a given training device, for integrating differing media into courses, and for designing total training systems to coordinate all phases of training. Separate instructional strategy efforts will be conducted during the period FY88 to FY89 to develop: (a) guidelines for optimizing feedback during electronic combat training, in which the real-time feedback requirements for implementation on operational ranges and the optimal format and content of post-mission debriefings will be determined (FY88); and (b) guidelines for the construction of combat training syllabi, in which the optimal training scenario content will be defined for close air support (A-10), daytime deep strike (F-16), and night attack interdiction (LANTIRN F-16) (FY89). A manual for total training systems design will be completed in FY92.

(2) Visual Scene Fidelity. Two additional efforts will be completed in the visual fidelity area during the period FY88 to FY89. Efforts planned are: (a) tactical simulator field-of-view requirements (FY88), in which quality of simulator task performance and transfer of training for full and limited field-of-view systems will be studied using ANG students; and (b) a handbook of visual scene requirements (FY89) for training low-level flight

skills. This handbook will be partly based on the performance of ANG students in a variety of visual scene conditions (different textures, 2- and 3-D object types and densities, sizes of objects, shadings, shadows, and atmosphere attenuation will be explored).

(3) Sensor Scene Fidelity. Sensor scene fidelity is another important issue in the TEP. During the period FY88 to FY89, investigations of infrared fidelity will be conducted. One set of efforts will evaluate the ability of subjects to determine basic characteristics of targets, such as orientation and classification, as a function of sensor image fidelity. Another set of efforts will determine the simulated infrared scene fidelity needed to train low-altitude terrain-following and navigation tasks.

(4) Simulator Instructional Technology. During the period FY88 to FY91, work will be conducted on multi-cockpit Instructor Operator Station (IOS) design guides and modular IOS software. The multi-cockpit IOS will be capable of interfacing with eventual prototype configurations on an in-house, two- to four-cockpit simulator by FY91. The modular software (developed as part of a joint-Service program) will be a standard IOS software package applicable to simulation in general. Three aircrew performance measurement efforts will be conducted during the period FY88 to FY91. The first effort will develop and validate plans for a stand-alone Performance Measurement System (PMS) which is capable of acquiring data from the Simulator for Air-to-Air Combat (SAAC) as well as Air Combat Maneuvering Instrumentation (ACMI) ranges. This common data base capability will be very useful for R&D purposes as well as for training progression purposes. A second effort will identify and quantify relevant pilot behaviors required to defeat threats and to accomplish mission objectives in surface attack maneuvers. A third will develop and evaluate a prototype Air Combat Assessment and Debriefing System (ACADS) for use with the F-16 aircraft. Specific components of this system will include: (a) a flight data recording system that can monitor and record the necessary parameters on-board the aircraft; and (b) a ground-based processing system that can process and present airborne data in a format suitable for performance analysis and replay after the aircraft has landed. ACADS will be functionally similar to an aircraft-mounted ACMI range system and will have the capability to be deployed to wing and squadron locations and used for local area training.

(5) Cost/Training Effectiveness Relationships. This issue is concerned with the design and implemention of a data base that can be used to consolidate existing information about cost/training effectiveness relationships and make it available when cost trade-off decisions must be made. During the period FY88 to FY89, AFHRL will work with the Army Research Institute (ARI) on the development and evaluation of an expert decision systems model that can be used to assist those responsible for device mix trade-off decisions. Work will also be conducted on the design specifications for a data base for operational implementation of these expert decision systems, with the assistance of DOD's Training and Performance Data Center (TPDC).

b. Simulator Technology for Aircrew Training Devices. The mission of AFHRL includes the design, development, and evaluation of new methods, equipment, and simulator devices for use in aircrew training. A wide variety of efforts along these lines is planned.

(1) New Components and Software Systems. New simulator components and software systems to be investigated are: (a) the use of non-linear focal length projection systems that will compress picture elements (pixels) near the center of the scene (FY89); (b) a thermal model to assign "gray shades" to portions of an infrared computer-generated image, based upon environmental conditions, so that forward-looking infrared (FLIR) sensors can be simulated (FY89); (c) new computer architectures that will make effective use of multiple microprocessors and parallel pipeline processing systems (FY92); (d) a universal imaging system data base that can be used for many different kinds of out-the-window, infrared sensor, and electro-optical TV displays (FY92); (e) field-deployable image generators (FY92); and (f) a variable acuity lens that would provide maximum effectiveness and minimum weight when used in conjunction with non-linear projection systems (FY92).

(2) Advanced Visual Technology Display and Software Systems. An Advanced Visual Technology System (AVTS) project was established in 1978, in order to develop and evaluate new concepts in visual technology systems. The project is oriented toward improved computer image generator (CIG) as well as improved visual display technology. Planned upgrades of the AVTS include providing the capability to fly two eye-tracked displays in independent aircraft within the computer-generated scene (FY89). Another important objective of AVTS is a full field-of-view dome display system, which is a joint effort involving AFHRL and Aeronautical Systems Division (ASD). As a result of this effort, a prototype full field-of-view dome display system for the F-16 will be integrated with the AVTS's CIGs. Once this system is operational (FY89), AFHRL and ASD scientists and engineers will evaluate its training utility for tactical flight simulation (FY91).

(3) Universal Imaging System. During the period FY89 to FY95, a universal imaging system will be developed. The goal of this effort is to develop a universal image generator that will flexibly generate all types of highly correlated source imagery for all required simulator images during combat mission rehearsal. Current image generators produce uncorrelated imagery for each separate visual or sensor display. Correlation of these data bases can be achieved only through a very labor-intensive and expensive process. This effort will start with a digital model of the geographic areas of interest, beginning with digital topographical data such as Defense Mapping Agency (DMA) terrain data. The digital model will next be overlaid with digitized photographic imagery data drawn from that geographic area. Targets, changing cultural and intelligence-based features, weather effects, and battlefield changes will also be added into the computer model using digital inputs. The resultant model will be used to generate all required (visual, FLIR, radar, etc.) simulator imagery. Data from this universal model will be processed in real time by a special-purpose computer system in order to generate any specific types of visual imagery required by the simulator.

c. New Concepts in Aircrew Training Systems. New concepts in aircrew training systems are being developed, including AI applications, a modular electronic warfare system, a low-cost fighter lead-in training simulator, a deployable combat mission trainer, interactive simulators with multiple cockpits, embedded training systems, a Tactical Training Center (TTC), and an integrated simulator system for Aircrew Combat Mission Enhancement (ACME).

(1) Artificial Intelligence (AI) in Aircrew Training. The initial goal in the AI area is to establish a knowledge base of pilot combat skills for use in aircrew training. It will include the areas of air-to-air, air-to-ground, and threat evasion techniques. AI will be used to break up tasks and develop part-task trainers that will use AI to optimize instruction and to model performance. Information on tactics and execution will then be incorporated into expert knowledge data bases for use in full mission simulator training exercises. A generalized AI model for use in part-task trainers will be developed in FY90. Expert systems for use in full mission simulators will be demonstrated in FY92.

(2) Modular Electronic Warfare Systems. Electronic combat training is difficult because of the complexity of the training to be provided, the unusual requirements for secure communications, and the rapid rate of technological change. Full mission simulators, on-board systems, and part-task trainers can all provide some of the training, but it is not clear how an overall system should be designed to effectively integrate the various components of aircrew electronic combat training. Modular components are needed, and AFHRL plans to develop a Modular Threat Training System (MOTTS) prior to FY89. MOTTS will then be used as input to a multi-threat, multi-ship, electronic warfare training system to be completed in FY91.

(3) Fighter Lead-In Trainer (FLIT). The FLIT visual display system will meet human visual training requirements in both field of view and in the ability to resolve image detail (resolution) at a much lower cost than that of conventional approaches which use many

channels of expensive image processors. The visual system to be developed for FLIT will use a specially designed image projection system that is slaved to the pilot's eyes. An eye-tracking device was designed for this system that accurately measures eye-viewing direction without restrictions to eye movements. This allows the image projector, coupled with the eye-tracker, to always keep the center of projected imagery in line with where the pilot is viewing (in the pilot's fovea). The system can consequently provide the highest level of detail at the center of the field of view, with decreasing acuity in the peripheries. The development of the display image generator and IOS needed for FLIT should be completed in FY88. After experimental evaluation and modification, an improved system will be demonstrated in FY90.

(4) Deployable Combat Mission Trainer. To meet the present goal of providing a Combat Mission Trainer (CMT) for both air-to-air and air-to-ground specific combat missions, a number of related objectives will have to be successfully accomplished. These include: helmet-mounted displays, optics, and eye-tracking refinements (FY89); and the fabrication of host computer systems adequate for both head/eye-slaved data processing and advanced cockpit avionics (FY92). Realization of a portable CMT for field unit deployment will require fabrication of a low-cost, field-hardened, high-fidelity portable image generator, a development that is projected to be within the state of the art for the proposed timeframe (FY92). The use of a CMT for mission rehearsal will require an automated data base development system capable of accurate scene generation from DMA and reconnaissance data (FY93). The complexity of full mission tactical training and rehearsal will require an automated instructional system that can integrate multivariate performance data into quickly understood performance diagnostics (FY93). The CMT must also incorporate adaptive logic to drive the simulated combat events at a level appropriate for the task load capacity of the pilot as he improves with training.

(5) Interactive Simulators with Multiple Cockpits. The requirements for multi-ship training are well documented in RED FLAG tests, where it was found that one-on-one combat experience did not adequately prepare pilots for multi-participant events. The problem with one-on-one simulated combat is that there are no free fighters or unobserved threats. The need for multi-cockpit simulators has been recognized by the Tactical Air Command (TAC), which has expressed interest in two interactive cockpits for the F-15E simulator and four interactive cockpits for the ATF simulator. New components, needed before these multi-cockpit simulators can be built, are being developed by AFHRL at Williams AFB, as indicated elsewhere in this report. Long-range plans call for a breadboard model in FY89, the assembly of a two-cockpit experimental system for the CMT in FY91, and a four-cockpit experimental system in FY93.

(6) Aircraft-Embedded Training Systems. In addition to ACADS (an embedded training system discussed elsewhere in this report), AFHRL will conduct work on a number of equipment-integrated systems in which on-board simulators (OBS) are used for training. One of these, being developed by AFWAL, is a new and improved Integrated Flight Fire Control (IFFC) system called Integrated Control Avionics for Air Superiority (ICAAS). The systems to be developed for ICAAS will permit use of embedded training systems designed and evaluated at AFHRL. Working jointly with AFWAL and ASD, AFHRL will develop specific training programs (prior to FY90) for: friend versus foe recognition, multiple target decisions, and team attack. Another function that AFHRL will perform in this area is to evaluate embedded aircrew training systems proposals for new aircraft. For example, AFHRL will evaluate embedded aircrew training systems concepts proposed for the ATF by the aircraft manufacturing contractors who are developing plans for this new weapon system. Training effectiveness studies using aircraft simulators, cost/benefit analysis studies, and transfer of training studies will be used to conduct these evaluations on an as-needed basis.

(7) Tactical Training Center. Training schools can easily adopt a total training systems approach, since a wide variety of training techniques are available to them. A TTC would establish a similar total training systems approach for continuation training at wing and

squadron locations. The basic ingredients of a TTC are an instrumented range system or its equivalent (ACADS can be used if one of the existing ACMI ranges is not readily within reach); a multi-cockpit simulator (at least two cockpits, but preferably four); and a deployable feedback/debriefing system. Additional ingredients to be considered are: special function trainers that are appropriately deployed to wing/squadron locations; and equipment-integrated training systems (e.g., the On-Board Electronic Warfare System being developed by the Armament Division). Important R&D objectives include: training device requirements (FY90); the analysis of embedded training alternatives (FY90); range, aircraft, and ground equipment requirements (FY92); and instructor, student, operator, and maintenance personnel resources (FY92). Aircrew members will eventually be guided through advanced combat training using these techniques, with the aid of computer-assisted training management systems (FY94) that would consider the availability of resources as well as the unique training needs of each individual aircrew member at that particular point in time. A great deal of information will be needed about the cost and training effectiveness of alternative training techniques in order to make this system work--but the rewards should more than pay for the effort required to design the system.

(8) Aircrew Combat Mission Enhancement (ACME). ACME is a Forecast II technology for which AFHRL is the lead organization. Forecast II resulted in an AFSC-wide program to develop 39 technologies and 31 advanced systems concepts that "will revolutionize the way the Air Force carries out its mission in the twenty-first century, guaranteeing continued technological supremacy over any potential adversary." The objective of ACME is to provide cost-effective simulator technology for combat mission training, mission rehearsal, and mission planning for tactical aircrews. This technology would be provided by: expediting the development of high-resolution, multi-spectral, geographic gaming areas; expediting the development of very high speed integrated circuits (VHSIC)-based computer systems that allow increased simulation capability while significantly reducing size and cost; developing the helmet-mounted display and multi-participant networking technologies required to support simulation of tactical combat tasks; and integrating diverse technologies to define combat mission training, mission rehearsal, and mission planning systems for high-threat environments. Other organizations working with AFHRL in the conduct of ACME are: AFWAL, the Rome Air Development Center (RADC), the Armstrong Aerospace Medical Research Laboratory (AAMRL), and ASD. Important milestones are: demonstrate integrated visual, infrared, and synthetic radar capability in the Advanced Visual Technology System (AFHRL/6.3/FY88); demonstrate ACME brassboard of airborne graphics generation system (AFWAL/6.2/FY38); demonstrate automatic vertical feature extraction (RADC/6.3/FY90); tactical networking concept definition (AFHRL/6.2/FY90); demonstrate brassboard miniature real-time computational system (AFWAL/6.3/FY91); demonstrate multi-source imagery merger and display (RADC/6.3/FY93); and delivery of computer image generation unifying device (AFHRL/6.3/FY96).

d. Evaluations, Demonstrations, and Handbooks. Evaluations, demonstrations, and handbooks are needed to facilitate the technology transition process.

(1) Demonstrations of Special Function Trainers (SFTs). A number of SFT demonstrations will take place during FY88. In addition to helping user organizations implement AFHRL products, these demonstrations will also provide AFHRL scientists and engineers with needed information about the effectiveness of SFT design alternatives. Important FY88 milestones include development of: an air-to-air radar intercept trainer for TAC; a crew coordination/penetration tactics trainer for the Strategic Air Command (SAC); an ECM trainer for MAC; and a KC-135 navigation intercept trainer for SAC.

(2) A Design Handbook for Special Function Trainers. Although R&D is not really needed to identify new concepts for most SFT applications, those responsible for designing SFT systems do not have up-to-date information about all of the options that are available to them, or the pros and cons of the various approaches that could be taken in the design of SFTs. Guidelines will be prepared to help future decision makers design SFT systems that will be both

cost and training effective. Important milestones are: the development of a part-task training methods decision support system (FY89) and the development of a handbook for SFT systems design (FY91).

(3) Initial Operational Test and Evaluation (IOT&E) of New Training Systems. AFHRL regularly provides consultants for the IOT&E of new aircrew training systems. This service is important for AFHRL as well as for its customers, since AFHRL scientists and engineers gain important insights into operational needs and problems as a result of their participation in IOT&Es. These IOT&E and consulting activities with respect to new training systems will continue throughout the planning period.

2. Command and Control (C^2) Training Systems. The evolution of the C^2 function in the Air Force is increasing both the challenge of training C^2 teams and the payoff of such training. Future C^2 systems will involve a network of interdependent nodes; if one node is destroyed during combat, other nodes will have to assume their functions. So, C^2 teams will have to be trained to perform a wider range of functions. In addition, the complexity of battle management will increase. With this increase come additional requirements to provide both realistic combat training opportunities and system design guidance to ensure that man-machine interaction requirements/design supports these increased operational demands. Consequently, training, human performance, wargaming, system design, and battle management decision making have emerged as major research interests.

a. AFHRL is responding to both the increased challenge and the increased potential payoffs by enlarging and upgrading its existing facility to focus on realistic C^2 training and human factors R&D. The facility will be electronically linked to both the Harry G. Armstrong Aerospace Medical Research Laboratory and the Rome Air Development Center--two other Air Force organizations with C^2 R&D responsibilities. Linkages to other DOD C^2 R&D facilities for support of the strategic defense initiative (SDI) are also planned. The upgraded facility will be used to identify better ways to train C^2 teams to function in all domains--tactical, strategic, and space operations.

b. The C^2 R&D program will continue to provide three kinds of products.

(1) Training to Improve Team Performance. This effort will develop technology to improve combat readiness training of individuals and teams assigned to the operational and logistics elements of the theater and force management levels--Tactical Air Forces (TAF). Part of the R&D will be to investigate the best ways of training personnel on the most effective methods to use when preparing air tasking orders (ATOs) and on training methods for high-level battle management decision making. In order to collect accurate and detailed information on wartime jobs (functions and tasks), an in-house effort to design and develop a computerized task data collection/analysis system is underway. When combined with a contracted effort, this new capability will allow collection of both procedural and decision-making data at the job site for C^2 positions in strategic, tactical, and space systems. This will provide the Air Force with an accurate, timely, and comprehensive data base for use in requirements analysis, training, assignments, system design, and operation. To improve the quality and reduce the cost of training and exercising C^2 battlestaffs, work aimed at developing both a better understanding of complex decision making and exercising/wargaming is underway. The work will include investigations of human performance/decision making in physically dispersed, functionally distributed operational sites, with emphasis upon the assessment of human memory capacity and automaticity. When completed, this work will lead to demonstration training prototypes, system design guidance, and exercise/wargaming recommendations for the operational forces. New analysis technology to accurately identify, collect, and manage the actual wartime training requirements for selected positions in the Tactical Air Control Centers (TACCs) will be developed. Work will also be conducted to develop knowledge engineering-based tools to provide customized, adaptive

training programs for functional-level training in tactical C^2 operations. The potential value of photographic-based visual imagery will be explored through a series of in-house studies to determine its value in training C^2 personnel. Photogrammatic techniques combine photographic images with mapping data to provide representations of actual terrain. The use of microcomputers to provide in-garrison training programs will be investigated. Demonstration prototype microcomputer-based exercise and training programs will be developed and field tested for both individual and team training.

(2) <u>C^2 Performance Assessment</u>. This R&D identifies variables that impact decision-making performance, and develops and validates criterion measures for these variables. Without these measures, understanding battle management processes is not fully possible. This effort will be accomplished in two phases. The first phase will extend technology now used in operational evaluation and operations research, and incorporate advancements in CAD technology to identify new distributed decision-making analysis methodology. The second phase will be to develop training/exercising methods to teach these skills and provide design guidance for systems to support distributed operations. The measures will be integrated with both large and small computer simulations now being used to train tactical C^2 personnel. Products resulting from this work will include: (a) complex information processing/decision-making analysis methods, (b) embedded performance recording and assessment techniques, (c) design guidance for new decision-aiding systems, and (d) prototype/training data base demonstrations.

(3) <u>Design Guidance and Evaluation</u>. Models will be developed to describe the internal information process (flow) for selected elements of C^2 systems to predict the impact that new automated equipment and software will have on the C^2 process. Through an exploratory initiative (6.1) and a research consortium with the University of Dayton, Wright State University, and the AAMRL, research will be conducted to gain a better understanding of the limitations and capabilities of human C^2 operators. This research is necessary to perform concept definition work for software design, display technology, and systems intended to aid the decision maker. Later work will document and verify design guidance and standards for use by RADC and the Electronic Systems Division (ESD) to better match the characteristics of new C^2 hardware/software systems with the capabilities of operators. The potential value of photographic-based visual imagery to improve tactical C^2 operations will be investigated. Work will initially focus on display requirements and use of overlaid graphics. It will continue with investigation of the actual utility of this technology for specific applications in mission planning, and comparisons with the effectiveness of current systems. Products resulting from the R&D on design guidance and evaluation include: (a) design data and recommendations for development, application, and evaluation of decision-aiding devices; (b) design data implications for the system operator of functionally distributed tactical C^2 operations; (c) human performance design data relevant to human memory capacity and automaticity; (d) predictive models of C^2 system processes; (e) user requirements analysis methods; (f) prototype system to assess human operator requirements; and (g) computer-aided human performance design tools.

3. <u>Technical Training Systems</u>. Increased emphasis is being given to the importance of well-trained personnel in maintaining combat readiness. R&D on technical training is aimed at enhancing job performance by developing improved training methods, better instructional and learning strategies, and enhanced techniques for managing training and evaluating job performance. Computer-assisted procedures are being developed to collect information about skill requirements, training management requirements, and job performance. Intelligent tutoring techniques will play an important role in the design of these new technologies.

a. <u>Planning and Managing Technical Training</u>. AFHRL is working to improve the way in which the Air Force decides what to train, when to train, and how to train.

(1) Training Decisions System. The Air Force must decide what skills to train personnel assigned to an AFS, when to train the skills, and where to train them. The decisions are made currently at periodic Utilization and Training Workshops, which bring together representatives from the training and personnel communities and from the user commands. In many circumstances, workshop participants have to make decisions with fragmented information about the impacts of their decisions on overall skill development within an AFS and on training costs. This effort will develop and demonstrate a prototype decision support system that will allow Workshop participants and other training decision makers to ask and answer "what if" questions. The prototype systems will be ready for transitioning in FY92.

(2) Technical Training Systems Planning and Evaluation. Consultants from AFHRL are frequently asked to participate in evaluations of new technical training system proposals and prototype devices. The Laboratory will increase its capacity to identify the mixes of training technologies that can meet given training objectives most cost effectively. This is an ongoing activity that will occur throughout FY88 to FY92.

b. Training Delivery. A major focus of AFHRL's work in technical training is, of course, the actual delivery of training. The Laboratory's efforts range from supporting the transition of previously developed training technologies to major weapon system programs, to expanding our understanding of new approaches and techniques.

(1) Alternative Training Delivery Systems. R&D on training delivery systems is designed to integrate emerging man-machine interface technology with computer-based training development and delivery technologies. This integration is intended to reduce dependence on traditional classroom and actual equipment for satisfaction of training requirements.

(a) Maintenance Training Devices and Diagnostic Aids. AFHRL will continue to examine the feasibility of using low-cost training devices to meet maintenance training needs. One possible approach, which will be developed and evaluated during FY88 to FY89, is a stand-alone maintenance troubleshooting trainer that will capitalize on the graphics capabilities of microcomputer-based devices for training and performance assessment.

(b) Improvements to Computer-Assisted Instruction (CAI) Authoring Systems. The effectiveness of existing CAI authoring systems will be assessed in FY87 to FY88, with emphasis on system capabilities, user-friendliness, and interfaces with other systems. During FY89 to FY92, a number of improvements to existing CAI authoring systems that would facilitate training materials development will be designed and evaluated.

(2) Intelligent Systems Technology for Training. In support of the Forecast II initiatives, AFHRL will lead an effort to develop and demonstrate intelligent tutoring systems (ITSs). The overall goals are: to establish a capability for conducting basic research; to establish a technology base in knowledge engineering; to develop prototype ITSs; and to demonstrate their efficiency in training for key Air Force specialties.

(a) ITS Knowledge Acquisition and Authoring Aids. Currently, ITS software is expensive to develop. Developing software for an operational ITS can require many manyears of effort by a team of highly skilled "knowledge engineers" and programmers. If development costs remain high, ITS will be limited to a small number of high-payoff applications. AFHRL is collaborating with the Naval Training Systems Center and ARI in an initial attempt to develop and demonstrate software tools which will allow authors with minimal instructional design and computer programming skills to develop intelligent training systems. If the program succeeds, it will bring down the cost of writing ITS software for at least a class of applications. The effort will extend into FY89.

(b) Intelligent Gaming Environments for Training. Embedding training in the content of a game can help motivate students and can increase retention of materials. Programming languages such as LISP are well suited to writing "intelligent" games, which can identify students' "knowledge gaps" and misconceptions and provide appropriate materials and exercises. In the FY88 to FY89 period, the Laboratory will develop intelligent instructional gaming environments for Space Command and ATC.

(c) Intelligent Man-Machine Interaction. This effort will focus on computer processing of natural language; it will develop modules and tools for the human-computer interface that will facilitate training and operational applications. The effort will support Forecast II's Virtual Man-Machine Interaction project technology as well as emerging systems such as the Super Cockpit. The effort will continue through FY88.

(d) Intelligent Coaching Systems. As a part of a joint-Service effort that will extend into FY88, AFHRL is supporting the development of intelligent tutors for the Ada and PROLOG programming languages. The goal of the work is to identify a set of technologically based principles that could be applied in other intelligent tutoring projects.

(e) Intelligent Computer-Assisted Training Testbeds (ICATT). The ICATT program will develop advanced prototype ITSs for training specific Air Force functions and demonstrate them in operating training environments. As the program is now envisioned, it will focus on training functions required by the Air Force's emerging space missions such as space shuttle launch control, space operations control, and satellite tracking. The ICATT program will start in FY88 and continue through FY92.

(3) Embedded Training. Embedded training systems are expected to be an intrinsic part of new equipment systems for non-aircrew personnel as well as for aircrew personnel. For example, aircraft fire control, radar, or ECM system assessment and repair can be simulated and taught on the aircraft itself, drawing upon computer components (e.g., processors, memory units) within various on-board computer-based systems, rather than being taught at locations away from the aircraft or taught by self-contained computer-based training units on the flight line. Moreover, any kind of equipment with a computer that is not used full time is a candidate for embedded training. As an initial venture in the embedded training area, AFHRL will work with the Electronic Security Command to embed computerized training in its SENTINEL System.

c. Performance Measurement. In FY88, a "hands-on" job performance measurement technique will be developed, evaluated, and compared with other measures of on-the-job performance. A follow-on to this effort will develop specifications for cost-effective performance measurement technologies. Data collected by using these techniques will be used to evaluate training and selection procedures. This work will be completed in FY92.

d. An Integrated Approach: The Advanced On-the-job Training System (AOTS). AFHRL is developing and demonstrating at Bergstrom AFB, Texas, a prototype system that will allow the Air Force to plan and manage on-the-job training (OJT), to deliver computer-based training at work sites, and to evaluate the training. It began in FY85, and will be completed in FY89. AOTS will establish training requirements for job positions, produce the format for an airman training record, enable automated scheduling and resource allocation, deliver training, and provide evaluation techniques.

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VI. PROGRAM RELATIONSHIPS

AFHRL maintains active technical coordination and cooperation with the Air Force Wright Aeronautical Laboratories (AFWAL), Logistics Management Center (LMC), Aeronautical Systems Division (ASD), Armstrong Aerospace Medical Research Laboratory (AAMRL), Air Force Acquisition Logistics Center (AFALC), and Rome Air Development Center (RADC). The Integrated Design Support (IDS) system and ABDR are two major projects AFHRL is jointly working with AFWAL. Participants with AFHRL in the development of Reliability and Maintainability in Computer-Aided Design (RAMCAD) include other Air Force agencies (AFWAL, RADC, and System Program Offices [SPOs]). Other participants in RAMCAD R&D include the Naval Ocean Systems Center, Fort Belvoir R&D Center, and the Picatinny Arsenal through the Joint Logistics Commanders' RAMCAD working group. Coordination is maintained with the Integrated Early Warning System (INEWS) SPO for a joint Maintenance and Logistics in Computer-Aided Design test, for which an AFHRL scientist serves as assistant chief of the reliability and maintainability evaluation. AFHRL is working with the Navy Personnel Research and Development Center (NPRDC) and the Army Research Institute (ARI) on tri-service automated technical data evaluation. The human model in CAD is a joint project between AFHRL and AAMRL. AFHRL personnel are members of the Joint Policy Coordinating Group for Logistics Research, Test, and Evaluation, plus several joint-Service subgroups such as the Reliability through CAD panel. Close coordination is being maintained with agencies that will use the products developed by AFHRL R&D. A formal Memorandum of Agreement between AFALC and AFHRL has been signed to promote orderly transition of R&D products. As part of the agreement, an AFALC officer is collocated at the Logistics and Human Factors Division (AFHRL/LR) to assist in the transitioning process.

Team Training Systems research is also coordinated with many agencies. Close liaison is maintained with elements of the Tactical Air Command (TAC), including support of BLUE FLAG exercises and evaluations at the Air Ground Operations School. Systematic technical coordination is maintained with the Army and Navy through international programs such as The Technical Cooperation Program (TTCP). Active interface is maintained with AAMRL's work on console design, man-machine interface, and communication and decision making for tactical commanders. Work toward achieving a comprehensive training capability for tactical C^2 teams is coordinated with RADC, the Electronic Systems Division, the 441st Tactical Training Group (BLUE FLAG), the Air Ground Operations School, the Air Force Military Personnel Center, Air University, the Ninth Air Force, the Twelfth Air Force, HQ AFSC, Air Staff, and selected Army and Navy organizations. Research and human information processing is conducted jointly with RADC. AFHRL's program is unique in its emphasis on training and evaluating Air Force tactical battlestaff members and commanders. Other programs make a contribution to this objective, but the AFHRL R&D is required in order to provide the Air Force with the full integrated technology that it needs.

Continuous technical exchange and coordination are also maintained in methodologies to support training system development, initial skills training, and on-the-job training. Effective liaison is maintained with pertinent industrial and educational programs. AFHRL is working with the Navy, Army, and several academic centers to coordinate the Air Force Artificial Intelligence (AI) program. The Office of Naval Research (ONR) is working with AFHRL in the development of computer-assisted instruction by participating in the Intelligent Computer-Assisted Instructional Network. A project jointly sponsored by the Naval Training Systems Center (NTSC), ARI, and AFHRL will develop a student diagnostic model along with knowledge acquisition tools and authoring aids for applying the module to training domains. Another project is sponsored by ARI, ONR, and AFHRL to build intelligent coaches for the Ada and PROLOG languages, with the objective of developing principles and guidelines for developing other coaching systems. AFHRL is also working with RADC to develop a computer-based speech recognition capability.

The Canadian and United States Governments are operating under a 50/50 cost-sharing agreement to develop a helmet-mounted display. The helmet-mounted display offers the potential of a

significant increase in brightness and resolution, at a substantial savings in cost over conventional dome and dodecahedron displays. The Navy (NTSC) is working on a competing design, and both will be ready for evaluation in the FY88 timeframe. AFHRL is also working with ARI and the DOD Training and Performance Data Center (TPDC) to develop expert systems for use by training systems designers.

The R&D to develop a pilot performance measurement system is being accomplished by the Air Force, the Navy, the National Aeronautics and Space Administration (NASA), the University of Illinois, and the Royal Air Force. In addition, the Army has several related research projects in the area of combat simulation, including work on a low-level sensor target identification system for attack helicopters. Both the Army and the Navy have ongoing research in simulator effectiveness and are working jointly on the development of microprocessor-based part-task trainers with advanced interactive display capabilities. A tri-service effort is also underway to develop standard data base formats for visual computer image generation (CIG) systems (Project 3851, ASD/YWB). Continuous coordination is maintained with the DMA on terrain presentation for low-level navigation and air-to-ground simulation.

Each year AFHRL actively participates in the review and evaluation of industry's Independent Research and Development (IR&D) programs. The scope of AFHRL's activities is illustrated by the actions that took place during FY86. AFHRL reviewed 69 company IR&D technical plans and found 382 projects relevant to the Laboratory. The largest number of relevant IR&D projects (195 projects with $91M proposed funding) was in the Logistics Technology area. Projects in this area were those concerned with logistics support analysis and forecasting; CAD and manufacturing; life-cycle costing; reliability analysis; automatic test equipment; automated technical orders/data; and command, control, communications, and intelligence (C^3I). During 1986, there was an increase in the application of AI to maintenance diagnostics and C^3I. The second largest area reviewed in FY86 was Training Technology (183 projects with $88.6M proposed funding). Projects in this area included both aircrew and technical training. Relevant projects were those concerned with flight simulator visual displays and image generation, simulation software, training technology applications, maintenance simulators, computer-based instruction, and Ada software developments. There were also numerous IR&D projects concerned with the application of AI and knowledge-based expert systems to aircrew and technical training, and pilot performance and workload studies. The Manpower and Force Management area had four relevant projects ($302K proposed funding) in personnel selection and occupational structure. AFHRL continues to actively solicit industry's interest in IR&D projects related to ongoing and planned Laboratory R&D programs.

VII. ACCOMPLISHMENTS

Some AFHRL accomplishments are summarized below by Technical Area.

Manpower and Force Management

1. Armed Services Vocational Aptitude Battery (ASVAB) Test Development. The ASVAB is the primary selection and classification device for enlisted entry to all the armed services. A version of the ASVAB is also used in the armed services national high school (institutional) testing program. By direction of the Assistant Secretary of Defense (Manpower, Installations, and Logistics), effective 1 January 1976, the Air Force was designated as Executive Agent for ASVAB research and development, with AFHRL as the lead DOD Laboratory. Thus, there exists an ongoing requirement for AFHRL to develop new versions of these tests, to validate and standardize them, and to perform R&D for ASVAB program involvement. On a cyclical basis, the ASVAB is

revised to accomplish one or more of the following objectives: (a) include new aptitude areas in the assessment of recruit abilities; (b) incorporate new psychometric techniques into the test development and standardization process; and (c) lessen the possibility of extensive compromise of the operational test. Accordingly, AFHRL has completed full development of three forms of the battery (ASVAB Forms 15, 16, and 17). These new forms will be implemented in October 1987 and replace ASVAB Forms 11, 12, and 13, which were previously developed by AFHRL.

2. Occupational Learning Difficulty Technology. An occupational measurement technology has been developed which employs experts' ratings of task learning difficulty to produce an occupational-level index of learning difficulty that can be meaningfully compared across occupations. The USAF Occupational Measurement Center is the immediate user of the R&D because the technology represents a significant extension and enhancement of the occupational measurement procedure employed by the Center. The utility of the occupational learning difficulty information produced by the technology resides in its use as a job-centered frame of reference for management decisions concerning the classification and training of enlisted personnel. The Air Force Military Personnel Center (HQ AFMPC) uses occupational learning difficulty information to determine test score minimums required for entry into enlisted job specialties. Air Force Recruiting Service (HQ AFRS) uses occupational learning difficulty information to determine initial job offers for Air Force enlistees. USAF Headquarters (HQ USAF/DPPTS) has recommended that learning difficulty indices be used as a basis for determining whether on-the-job training or formal resident training is appropriate for a given job specialty. Furthermore, occupational learning difficulty data have been submitted as the evidentiary basis for job entry requirements when those requirements have been subjected to Congressional review (SASC/HASC) or review by oversight committees (Defense Advisory Committee on Military Testing; Government Accounting Office).

3. Portable Basic Attributes Tests (PORTA-BAT) System and Pilot Candidate Selection Method (PCSM). The PORTA-BAT and the PCSM are interim products of a multi-year R&D program to improve the selection of pilot and navigator candidates and develop a track selection procedure for Specialized Undergraduate Pilot Training (in which student pilots will be assigned to either the fighter-attack-reconnaissance or tanker-transport-bomber training track). A critical component of this R&D has been the development of new types of ability tests which will predict later flying performance. Capitalizing on the advantages of computer technology, a battery of tests called the Basic Attributes Tests (BAT) was developed to measure a person's hand-eye coordination, information processing capabilities, and personality and attitudinal characteristics. To be able to administer these tests reliably at any location, without highly trained administrators, a self-contained, auto-administering computer test system called the PORTA-BAT was developed. From the results of this program, a more accurate PCSM was developed. The PCSM uses scores from the PORTA-BAT and the Air Force Officer Qualifying Test (AFOQT), biographical information, and grades from the Flight Screening Program (FSP). These pieces of information are combined by PCSM, and a final score is produced for the candidate which reflects his/her chances of completing pilot training. Plans call for PCSM to be used at the completion of the FSP as the final decision mechanism for entry into pilot training. According to estimates from ATC, $2-6 million a year will be saved from attrition costs when PCSM is used operationally.

4. Processing and Classification of Enlistees (PACE) Classification System. During Basic Military Training, personnel classified into an aptitude area (Mechanical, Administrative, General, or Electronics) are assigned by the PACE system into specific Air Force specialties (AFSs). The present PACE classification system generates a payoff value (a measure of the value of assigning the person to an AFS) for each available AFS for which the enlistee is eligible. Personnel are currently classified using a computerized sorting process according to payoffs. The new classification system, developed in conjunction with users at ATC, will use a new payoff function designed to ensure that ATC managers can efficiently meet training goals while improving the overall effectiveness of the match between person and job. The new PACE system optimally

classifies personnel by maximizing the sum of payoffs that can be realized through the assignment process. Implementation of the new PACE classification system will involve replacement of the present sorting process with a new software module. After the system determines the AFSs for which each person is eligible, this information will be downloaded to a microcomputer along with other information needed for generating the payoffs. After the payoffs have been generated, the new optimization routine will classify personnel using linear programming techniques. Once the microcomputer results are acceptable to management, the results will be uploaded so that the mainframe PACE computer can complete the classification process.

5. Training Decisions System (TDS) Demonstrator. The TDS demonstrator is an interim microcomputer-based system designed to provide demonstrations and user evaluations of the TDS. The goal of the TDS is to provide training policymakers with advanced modeling capabilities to aid in developing optimal, overall training designs for enlisted Air Force career ladders. The TDS demonstrator provides potential TDS users with an opportunity to interact with and query the system to see how improved, cost-effective training decisions may be possible. The TDS demonstrator uses a combination of actual and simulated data to clarify the advantages that can be accrued from being able to answer "what if" training questions. The TDS demonstrator's ability to model such important factors as cost, assignment, and training capacity, and consider them early as an integral part of the Air Force training system development process, demonstrates how the Air Force may make more informed decisions by using the TDS. The TDS demonstrator is very user-friendly with its color displays, help screens, and diagrammatic representations. The menu-driven features used in the TDS demonstrator allow a manager with little or no computer background to see how the TDS would help develop the most cost-effective training possible while considering information about job tasks, assignment patterns, and managers' preferences.

Logistics Technology

1. Computer-based Maintenance Aids System (CMAS). Two draft specifications for a CMAS were developed for use in procuring an automated technical data system for operational use. The first specification defines the content of technical data to be presented on the automated system. It specifies the specific categories of information to be included, the required content for each type of data, the formats in which the data are to be presented, and the data relationships (e.g., branching instructions) for the data. The second specification defines the functional requirements for an automated technical information system. It specifies requirements such as response times, data base management, presentation of graphics, and man-machine interface techniques. The specifications will be made available to technical data managers in the Air Force Logistics Command, SPOs, and the Major Commands for use in procuring automated technical data presentation systems and technical data for presentation on those systems. Operational use of CMAS will significantly reduce the cost of maintaining the technical order system, by reducing the cost of updating technical data and printing cost. In addition, the improved usability of and easy access to maintenance instructions are expected to improve maintenance performance.

2. Ground-Launched Cruise Missile (GLCM) Redesign. This program provided hard evidence of the benefits of using CAD to address maintenance support issues. The GLCM turbine power generator for the Transporter Erector Launcher and the Launch Control Center of the GLCM system were redesigned. The CAD effort sponsored by AFHRL made 28 design recommendations, of which 21 were accepted and incorporated into the new equipment. These recommendations resulted in an 8% increase in the availability of the turbine system--from 76% to 84%. Given the planned 60-unit buy, this translates into 4 additional turbines or 16 additional missiles.

3. F-15E Turnaround and Reconfiguration Simulation (TARS). With the future deployment of F-15Es in a European protective shelter (TAB-VEE) environment, it was recognized that significant

problems associated with aircraft turnaround and reconfiguration could arise. To prevent this occurrence, a joint effort with the F-15 SPO was undertaken to determine if these problems exist. A CAD-based system was used to analyze and evaluate the turnaround and reconfiguration tasks associated with the F-15E and its deployment in Europe. The overall objective of this effort was twofold: (a) to evaluate problems with the F-15E prior to deployment, eliminating the need for live on-site demonstrations; and (b) to demonstrate and evaluate the benefits of computer-assisted technologies for Maintenance and Logistics Factors in Computer-Aided Design (MLCAD). The results of these MLCAD demonstrations have identified the F-15E turnaround activities within the TAB-VEE shelter as a maintenance operation that lends itself to CAD simulation and analysis. Any problems associated with the F-15E's turnaround and reconfiguration in a TAB-VEE shelter can be determined prior to deployment. In addition, this effort demonstrated to Government and industry that CAD and computer-aided engineering techniques lend themselves quite readily to supportability analysis, and that these analyses can be applied early in the design cycle, thus allowing supportability design decisions to be more effective.

4. Limited Objectives Computer Graphics Model of the Maintenance Technician (CREW CHIEF). Maintainability and supportability of weapon systems have been traditionally evaluated by performing maintenance tasks on mockups or prototypes after the design has been established. Changes to correct deficiencies at that point are costly. Now that CAD technology is in wide use by Air Force contractors, digital representations of the hardware and the maintenance technicians have been developed so that maintainability can be graphically evaluated while the design is fluid. The currently available version of CREW CHIEF presents a biomechanical representation of the maintenance technician that is significantly enhanced to include hand movements, tool manipulation, and mobility. Such characteristics as reach limits and strength capabilities of male and female maintenance technicians are included. Through the use of CREW CHIEF, design-induced maintenance problems can be identified during the preliminary design phase and appropriate modifications can be made before the design has been finalized, saving both dollars and man-hours.

5. Logistics Impacts of Future Gunships. This work developed and demonstrated methodology that was used to quantify the sortie generation capability and maintenance manpower requirements for a hypothetical, but representative, state-of-the-art gunship. The improved gunship was defined to be a modified version of the current AC-130H gunship. Modifications involved the avionics, communication, navigation, and mission equipment subsystems. The tool used to perform this analysis was the LCOM model. The approach taken was to create an LCOM model of the baseline AC-130H and then modify this model to represent the improved SOF-30 gunship, which resulted in a quantification of the impact of changes in hardware reliability on maintenance manpower requirements. This work demonstrated for the first time that quantitatively oriented front-end logistics analyses during a systems conceptual design phase are possible. Another conclusion was that equipment reliability improvements alone will not produce significant reductions in maintenance manpower requirements. This must come from the synergistic effect of improvements in other supportability factors such as the maintenance concept, specialist compression, aircraft basing mode, and other "ilities." The results of this effort are being used by the Air Force (ASD) and the SPOs for gunship development programs.

TRAINING TECHNOLOGY

1. Fiber Optic Helmet-Mounted Display (FOHMD). The FOHMD is a joint US/Canadian program to develop a low-cost, lightweight, high-quality alternative to large dome or mosaic display systems for tactical mission simulation. This technology provides the color, high-brightness, high-resolution, and wide field-of-view display required for advanced tactical air-to-air and air-to-ground training without the high cost and transportability problems inherent in large visual display domes. The FOHMD projects the visual scene from "light valves" via fiber optic

bundles onto lenses mounted on a helmet, directly in front of the pilot's eyes. A brassboard prototype of the helmet has been developed which utilizes head-tracking to determine what visual scene needs to be projected on the helmet. This helmet is currently being evaluated for its training effectiveness. The final version of the helmet will utilize eye-tracking. Eye-tracking provides a more accurate visual scene but is more difficult to accomplish. The FOHMD technology is significantly advancing the state of the art in flight simulator visual systems. This system will eliminate the very large and costly optics needed to wrap around an entire cockpit and will provide low-cost portable visual display systems for front-line readiness training. The FOHMD will eventually be the visual display for a multi-cockpit, multi-sensor combat mission simulator to train pilots in complex tactical missions over simulated enemy terrain.

2. Flight Simulator Transport Delay Analysis. As aircraft simulators become increasingly complex and expensive, their ability to provide realistic training becomes an ever-growing concern. With the typical state-of-the-art simulation for tactical fighters costing in the neighborhood of $10 million, it is becoming essential to develop a method for simulator evaluation prior to acceptance. To do this, a data base was established to predict the amount of transport delay that can be tolerated for a given aircraft/mission combination. This information is used to determine the computational requirements before the simulator is assembled and avoid the expense of modifications and expansions of the system after-the-fact. This information will be used by the Air Force (ASD/YW) in evaluating the acceptability of proposed simulator designs.

3. Instructor Operator Station Design Specifications. These specifications were the result of a joint effort with the Simulator System Program Office (ASD/YW) on the utilization of instructor operator stations for flight simulators. The effort determined those features which were actually used by the major commands, those which needed modification, and those which were needed but not built into current simulators. This information has been published and distributed to a variety of users who establish the operational requirements for new simulators. This information has been provided to ASD/YW for use in developing specifications for future simulators.

4. Radar Warning Receiver Part-Task Trainer Specifications. A prototype Radar Warning Receiver (RWR) part-task trainer was developed which simulates common RWR equipment and ECM systems used in many tactical aircraft. Training tasks include equipment operation, malfunction analysis, symbology interpretation, and optimum ECM responses. An evaluation by Tactical Air Command (TAC) showed that the RWR part-task trainer made a significant contribution to improving the skill level of aircrews at minimum cost, since it required neither flight time nor the use of a full mission simulator. The United States Air Forces in Europe (USAFE) requested the software specifications for this system and provided them as Government-furnished equipment to a contractor who is developing a similar system for use in the European theater. The Air Staff has directed that RWR part-task trainers be developed for the entire Air Force. These part-task trainers will be modeled after the prototype developed by AFHRL.

5. Intelligent Maintenance Aid (IMA). The primary products of this R&D are computer software and manuals for an expert system in maintenance job aiding. IMA is an intelligent expert sytem for job aiding in avionics maintenance on the F-111 6883 test station. The computer language used was INTERLISP-D and the program runs on a XEROX 1108 LISP processor. The IMA has a multiple-interface capability for user information (how to, where to, where from, explanation, browse, why, backtracking, graphics). This R&D has laid the groundwork for extending IMA from a job aider to an expert system-driven tutor, giving the Air Force AI instructional/tutorial capabilities.

VIII. RESOURCES

AFHRL manages approximately $60 million per year, of which about 25% is used for in-house R&D and for Laboratory operations. The remainder is used to obtain the expertise and capabilities of industry and universities in the development of new technologies for personnel selection, training, and utilization. The Laboratory employs approximately 400 military and civilian scientific, engineering, administrative, and support personnel. About half of these are in professional categories, and are mostly psychologists, engineers, computer scientists, and operations research analysts. Approximately 40% of all personnel have advanced degrees.

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